CETRA2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA^{2012}
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

ORGANISATION

CHAIRMEN

Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering
Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Ronald Blab, Vienna University of Technology, Austria
Prof. Vesna Dragčević, University of Zagreb, Croatia
Prof. Nenad Gucunski, Rutgers University, USA
Prof. Željko Korlaet, University of Zagreb, Croatia
Prof. Zoran Krakutovski, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. Stjepan Lakušić, University of Zagreb, Croatia
Prof. Dirk Lauwers, Ghent University, Belgium
Prof. Giovanni Longo, University of Trieste, Italy
Prof. Janusz Madejski, Silesian University of Technology, Poland
Prof. Jan Mandula, Technical University of Kosice, Slovakia
Prof. Nencho Nenov, University of Transport in Sofia, Bulgaria
Prof. Athanassios Nikolaides, Aristotle University of Thessaloniki, Greece
Prof. Otto Plašek, Brno University of Technology, Czech Republic
Prof. Christos Pyrgidis, Aristotle University of Thessaloniki, Greece
Prof. Carmen Racanel, Technical University of Bucharest, Romania
Prof. Stefano Ricci, University of Rome, Italy
Prof. Tatjana Rukavina, University of Zagreb, Croatia
Prof. Mirjana Tomičić–Torlaković, Univiversity of Belgrade, Serbia
Prof. Brigita Salaiova, Technical University of Kosice, Slovakia
Prof. Peter Veit, Graz University of Technology, Austria
Prof. Marijan Žura, University of Ljubljana, Slovenia

THE COMPARISON BETWEEN WHEEL TRACKING AND TRIAXIAL CYCLIC COMPRESSION TEST ON DIFFERENT ASPHALT MIXTURES

Nataša Zavrtanik[1], Roman Bašelj[1], Mitja Kozamernik[1], Goran Turk[2], Marjan Tušar[3]
1 IGMAT d.d., Building materials institute, Slovenia
2 Faculty of civil and geodetic engineering, University of Ljubljana, Slovenia
3 National institute of chemistry, Slovenia

Abstract

Road structural materials should have satisfactory behaviour that enables a proper load carrying capacity. Asphalt mixtures used in road construction must be resistant to permanent deformations and cracking caused by temperature changes and fatigue. Road damages caused by the impact of different factors don't have equal impact on all layers of road construction and can manifest in various forms.
To determine the resistance to permanent deformations at high temperatures of asphalt specimens, triaxial cyclic compression and wheel tracking tests were done. We have made wheel tracking tests according to the SIST EN 12697-22standard and triaxial cyclic compression tests according to the SIST EN 12697-25 standard, method B. Experiments were done for all asphalt mixtures regularly used in Slovenia: AC, SMA, MA and PA to obtain an extensive model of asphalt behaviour for mixtures containing high and low air void content. Mastic asphalt dictated the use of harder bitumen in all mixtures with the intention to compare results of wheel tracking test and cyclic compression test for four asphalt mixtures. The results will be interpreted with a statistical model.

Keywords: asphalt mixtures, triaxial test, wheel tracking test, proportional rut depth, strains, stability

1 Introduction

Our main intention was to obtain an extensive model of asphalt behaviour for mixtures containing high and low air void content. We would like to compare the results of triaxial tests and wheel tracking tests for all types of asphalt mixtures regularly used in Slovenia: Asphalt Concrete (AC), Stone Mastic Asphalt (SMA), Mastic Asphalt (MA) and Porous Asphalt (PA). All tested asphalt mixtures have maximal grain size of 11mm and were once mixed with road bitumen B20/30 and once with polymers modified bitumen PmB10/40-65. Here we have to mention, that triaxial cyclic compression tests were done on Slovenian asphalt mixtures for the first time. We intended to compare results of wheel tracking test and cyclic compression test for four asphalt mixtures. The main goal of this study was a calculation of an accurate model for relation between wheel tracking test and cyclic compression test.

1.1 Short review of literature

In [1] and [2] authors describe new approaches to asphalt testing, which is performance based testing. Among other things they describe also the triaxial cyclic compression test.
Because conventional test methods used to indicate the resistance against rutting don't discriminate between convention and modern mixes, now in Netherlands cyclic triaxial test are used. Author in [3] describes a method in which the triaxial test data is used to predict the rut propagation on asphalt concrete. In [4] authors measured creep compliance for dense asphalt mixtures and porous mixtures depending on different shapes of wave-form of applied load and different test specimens height. Paper [5] presents a study of effect of air voids content on the mixture strength properties. Researchers investigated two mixtures (Dense Graded Mix and Stone Mastics Asphalt) with triaxial shear strength test. In [6] authors investigated the rutting behaviour of bituminous materials with different air void contents.

2 Materials and tests

2.1 Binder, aggregate, binder and void content

All mixtures were made out of two types of binder: road bitumen B20/30 and with polymers modified bitumen PmB10/40-65.
Asphalt mixtures were made of limestone aggregate with maximum grain size which passes through square sieve with maximum size of 11 mm. With the intention of result comparison of wheel tracking test and triaxial cyclic compression test, all four asphalt mixtures were made out of same limestone aggregate with equal maximum grain size (AC11, SMA11, PA11 and MA11).
Table 1 presents binder and void content values of asphalt mixtures. It is seen that for all tested types of asphalt mixtures containing polymers modified bitumen have more voids than asphalt mixtures containing paving grade bitumen. This can be explained with higher resistance to compaction of asphalt mixtures containing PmB, due to higher softening point of PmB binder. Softening point (ring and ball test) for PmB10/40-65 is measured at75.1°C and for B20/30 is 62.9°C. But it is also known that even if the softening points of PmB (with SBS modifier) and paving grade bitumen are the same, it is always harder to compact asphalt mixtures containing PmB.

Table 1 Binder and void content, binder and void content values of asphalt mixtures.

Property	**Binder content (m/m) [%]**	**Filler content (m/m) [%]**	**Void content (V/V) [%]**	**Void filled with bitumen [%]**
Method	EN 12697-1	EN 12697-2	EN 12697-8	EN 12697-8
AC	5.2	7.7	2.5	83.4
AC PmB	5.2	7.7	3.6	77.4
SMA	6.5	8.0	2.3	86.6
SMA PmB	6.5	8.0	2.9	83.5
PA	5.0	3.6	15.8	39.3
PA PmB	5.0	3.6	19.8	32.8
MA	7.0	27.2	1.5	91.6
MA PmB	7.0	27.2	1.9	89.7

2.2 Triaxial cyclic compression test

We have conducted a triaxial cyclic compression test according to the SIST EN 12697-25 standard, method B. The cylindrical specimen in the triaxial test is subjected to a confining stress and a cyclic axial stress at elevated conditioning temperature and vertical plastic deformation is measured. Specimens are subjected to the constant confining pressure σ_c and haversinusoidal cyclic vertical pressure σ_a. Test specimens were prepared in the laboratory by an impact compactor (Marshall specimens). High-to-diameter ratio of the specimens was 0.6, because of the nominal aggregate size of 11mm. Test temperature was 50°C for all specimens. Fig. 1 represents permanent deformation curves depending on the number of load cycles. We can notice, what is also expected, that mastic asphalt (MA) is far away from others and also mixes with polymer modified bitumen behave better under cyclic compression load than mixes with road bitumen do.

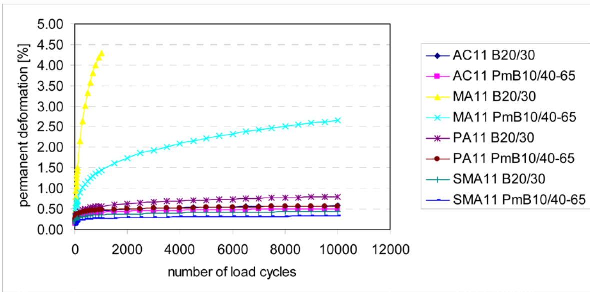

Figure 1 Permanent deformation curve for different types of asphalt.

2.3 Wheel tracking test (WTT)

We have made wheel tracking tests according to the SIST EN 12697-22 standard with a small – size device in the air (procedure B). Specimens for all asphalt mixtures were laboratory prepared. Thickness of the specimens was 40 mm, because mixtures with maximal grain size of 11mm were tested. Test temperature was 60°C for all specimens. This temperature is required in Slovene national specifications. Fig. 2 represents permanent deformation curves depending on the number of load cycles. We can notice, what it is again expected, that mastic asphalt (MA) is far away from others types of asphalt. Very similar are deformation curves for AC and SMA made of polymer modified bitumen and they have also the best behaviour under load.

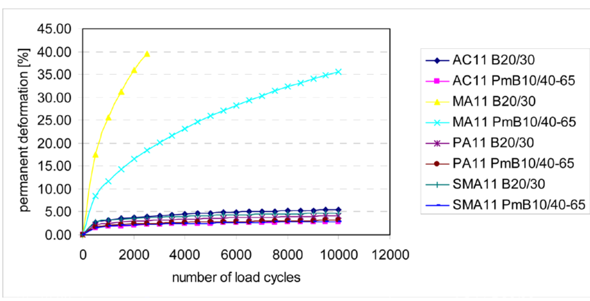

Figure 2 Permanent deformation curve for different types of asphalt.

2.4 Marshall stability test

Additionally, on all asphalt mixtures the Marshall stability test, according to the EN 12697-34 standard was performed. In new European standards for asphalt specifications (standards EN 13108) this test is required only for airfields. In the past this test was mainly performed on AC mixes in scope of quality control. We expected some relevant results due to the fact that the test temperature is 60°C; this is the same as wheel tracking test temperature. It should be stressed that for the SMA samples it is hard to determine the point of maximum force. This mostly affects the accuracy of flow (F) determination. Results of the Marshall stability test for SMA have shown, that at the steepest part of curves slopes are reproducible. What makes a more accurate and reliable parameter than flow (F) is determined from the slope of tangential flow (Ft). For modelling we decided that it is better to take into account the tangential flow (Ft) than flow (F). Instead of Marshall quotient (S/F), quotient between stability and tangential flow (S/Ft) was used for modelling.

3 Test results

From Figures 3 and 5 it can be seen that results of wheel tracking and triaxial test for mastic asphalt (MA) were far from the result for other types of asphalts. Due to extensive permanent deformations both tests on MA samples containing paving grade bitumen were stopped before the end of test. Table 2 shows some final results.
First we assumed that strain (ε_{10000}) and proportional rut depth are related so we graphically compared results (Fig. 3 and Fig. 4). From Fig. 3 it can be seen that asphalt mixtures containing PmB are, for all four types of asphalt mixtures, more resistant to rutting than asphalt mixtures containing paving grade bitumen B20/30. Surprisingly, from Fig. 4 it can be seen that both SMA asphalt mixtures (containing PmB and containing paving grade bitumen B20/30) are more resistant to permanent deformation than other asphalt mixtures when triaxial test is performed. It must be stressed that wheel tracking test according to EN 12697-22 was performed at 60°C and triaxial test according to EN 12697-25 at 50°C. From Table 2 it can be seen that values of tangential flow (Ft) for asphalt mixtures containing PmB are not always lower than for asphalt mixtures containing B20/30. From this we can conclude that simple relations between usage of modified bitumen and asphalt properties are not a rule.

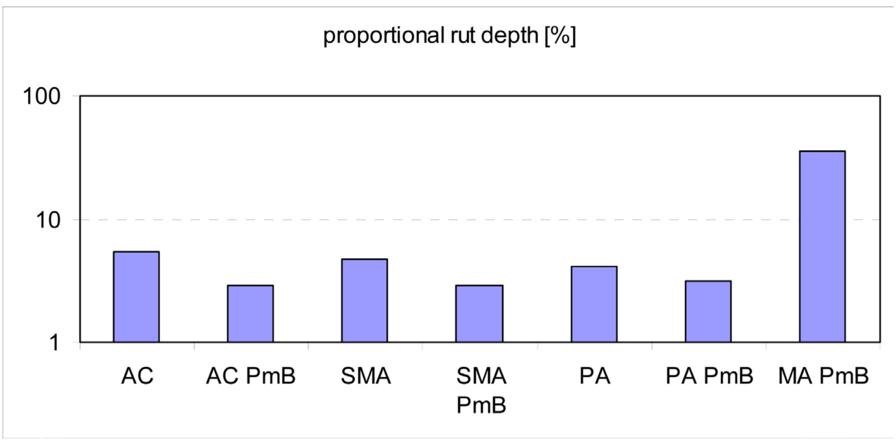

Figure 3 Proportional rut depth for 7 asphalt mixtures is a result of the wheel tracking test according to EN 12697-22.

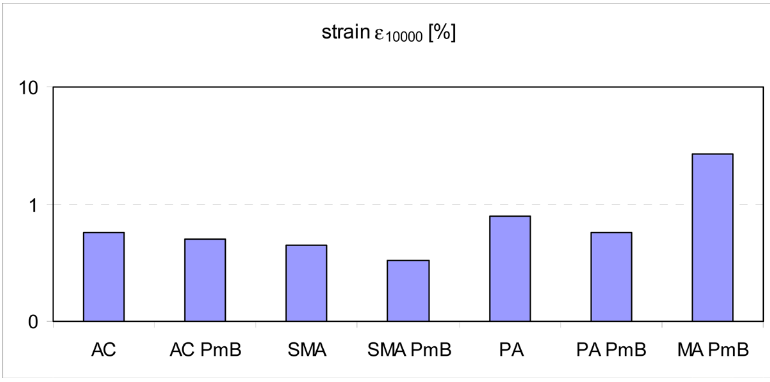

Figure 4 Strain (ε_{10000}) for 7 asphalt mixtures as one of the results of triaxial test according to EN 12697-25.

Table 2 Results of mechanical tests on asphalt mixtures.

Property	Stabil. (S)	Tangent. flow (Ft)	Quot. (S/Ft)	Strain (ε_{10000})	Max. def.	Proport. rut depth	WTS
	[kN]	[mm]	[kN/mm]	[%]	[mm]	[%]	[mm/1000]
Method EN 12697	34	34	34	25	25	22	22
AC	17.6	2.5	7	0.577	0.367	5.44	0.059
AC PmB	20.4	2	10.2	0.505	0.322	2.87	0.026
SMA	11.3	1.4	8	0.442	0.285	4.73	0.046
SMA PmB	13.7	1.8	7.9	0.329	0.210	2.87	0.028
PA	8.4	1.1	7.9	0.799	0.487	4.11	0.046
PA PmB	8.9	1.5	5.9	0.569	0.352	3.16	0.031
MA PmB	20.9	4.9	4.3	2.657	1.646	35.5	0.785
MA	21.4	3.4	6.3	4.292 (1000 load cycles)	2.637 (1000 load cycles)	39.6 (2500 load cycles)	-

4 Modelling

First we checked the simple linear relation between strains (ε_{10000}) obtained with the triaxial test and proportional rut depth. From Fig. 5 we can see that correlation coefficient is promising if MA PmB is included (left), but there is practically no relation for other asphalt mixtures (when MA PmB not included) (right).
To improve the model we included data from the asphalt composition and the Marshall test. We selected bitumen content, content of stone aggregates passing characteristic sieve of 2mm and quotient between stability and tangential flow. With the linear model we obtained an extremely good correlation coefficient when MA PmB data is included (r^2=0.9996) and fairly good (r^2=0.981) when MA PmB data is excluded from the training set. In Table 3 we can compare measured results of proportional rut depth and proportional rut depth calculated from the linear model of type:
Proportional rut depth (%)= a1*(strain (ε_{10000})) + a2*bitumen [%] + a3*2 mm [%] + a4*S/Ft + b.
We must be aware that such a model is useful only for asphalt mixtures with maximum grain size of 11mm and limestone aggregate, but it can be the base for a more common model. For other asphalt mixtures we can expand the model with including additional factors, such as bitumen softening point, filler content and content of stone aggregates passing all other sieves of 2mm etc.

In future we will try to validate the proposed model with additional experiments on asphalts with different sieving curves and different bitumen origin. It is strange that in the proposed model softening point and filler content were not selected as factors, but we suppose that the results from the Marshall test also inherently include some about data softening point and filler content. For the second model we used measured proportional rut depth after 2500 load cycles instead of the proportional rut depth after 10000 load cycles and strain after 1000 load cycles (ε_{1000}) instead of the strain after 10000 load cycles (ε_{10000}). In the second model we were able to include data from MA asphalt mixture containing paving grade bitumen (B20/30). When all eight asphalt mixtures were included in the linear model, we again obtained good correlation coefficient (r^2=0,998).

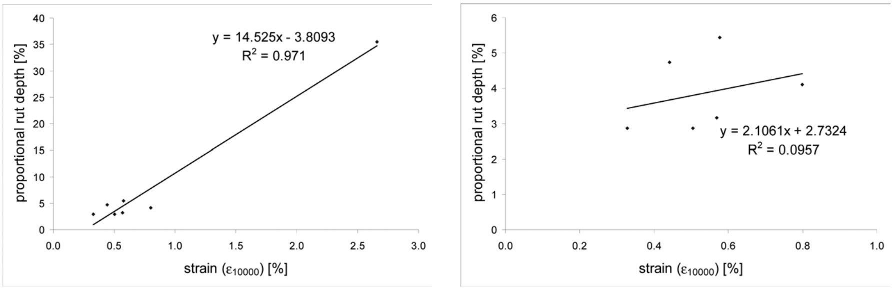

Figure 5 Proportional rut depth/strains (ε_{10000}).

Table 3 Results of measured Proportional rut depth and Proportional rut depth calculated from the linear model mixtures.

Property	Measured proportional rut depth [%]	Calculated proportional rut depth [%]
Method	**EN 12697- 22**	**Linear model**
AC	5.44	5.55
AC PmB	2.87	2.77
SMA	4.73	4.37
SMA PmB	2.87	3.23
PA	4.11	4.29
PA PmB	3.16	2.97
MA PmB	35.5	35.51

5 Conclusion

We've made wheel tracking tests and triaxial cyclic compression tests for all asphalt mixtures regularly used in Slovenia: AC, SMA, MA and PA. First we expected a simple linear relation between results obtained with triaxial test and results obtained with the wheel tracking tests, but we found poor correlation. When we included data from the Marshall stability test, bitumen content and content of stone aggregates passing characteristic sieve of 2mm in a linear model we got extremely good correlations. Due to the fact that the selected statistical model includes mixtures containing high and low air void content we expect it can be useful for a rough prediction of rut propagation from the triaxial cyclic compression test and the Marshall stability test results.

Acknowledgement

This work has been financially supported by the European Union, European Social Fund. The support is gratefully acknowledged.

References

[1] Brown, E.R. & Kandhal, P.S. & Zhang, J.: Performance testing for hot mix asphalt, NCAT Report 01-05, Auburn University, 2001.

[2] Tušar, M.: Strokovni prispevki, Novosti pri laboratorijskih preiskavah, ZAS, Od skupščine do skupščine 11., ZAS, pp. 23-26, 2007.

[3] Huurman, N.: Cyclic triaxial tests on asphalt concrete relating to rutting, 2th Eurasphalt & Eurobitume, Barcelona, pp. 351-363, 2000.

[4] Huurman, J.M.M. & Huurman, A.A.A.: Susceptibility to permanent strain of asphalt in the dynamic triaxial compression creep test, 2th Eurasphalt & Eurobitume, Barcelona, pp. 490-499, 2000.

[5] Pellinen, T.K. & Song, J. & Xiao, S.: Characterization of hot mix asphalt with varying air voids content using triaxial shear strength test, 8th Conference on asphalt pavements for Southern Africa, South Africa, 2004.

[6] Popp, K., Kruse, H. & Kaiser, I.: Nonlinear properties analyses on rutting behaviour of bituminous materials with different air void contents, Construction and Building Material, 23, pp. 3492-3498, 2009.